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Gene × Environment Interactions in Early Externalizing Behaviors: Parental Emotional Support and Socioeconomic Context as Moderators of Genetic Influences?

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

Elliot M. Tucker-Drob

Caryn L. Carlson

Gene × Environment Interactions in Early Externalizing Behaviors: Parental Emotional Support and Socioeconomic Context as Moderators of Genetic Influences?

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Amanda Kingsze Cheung, B.S.

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Abstract

Gene × Environment Interactions in Early Externalizing Behaviors: Parental Emotional Support and Socioeconomic Context as Moderators of Genetic Influences?

Amanda Kingsze Cheung, M.A.

The University of Texas at Austin, 2015

Supervisor: Elliot M. Tucker-Drob

Previous findings on gene × environment interactions on externalizing behaviors have been inconsistent. In an attempt to provide clarity on this inconsistency, our study used two longitudinal population-based samples of young twins to examine the independent effects of two moderators commonly studied in the externalizing literature. Our first sample, the twin subsample from the Early Childhood Longitudinal Study-Birth Cohort (ECLS-B), was composed of approximately 600 twin pairs measured on externalizing at ages 4 and 5. We tested for gene × parental emotional support and gene × socioeconomic status interactions on externalizing. Results indicated stronger genetic influences on externalizing at higher levels of parental emotional support but also at lower levels of socioeconomic status. These moderation effects, however, were not replicated in our analyses of the National Longitudinal Survey of Youth-Child Supplement (C-NLSY) data, which contained 2370 pairs of siblings measured on

externalizing at ages 4-5 and ages 6-7. Our results highlight the need for replication in quantitative behavior genetics research on externalizing behaviors.

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Introduction[1]

Externalizing refers to a constellation of behaviors that deviate from social norms. These include aggression, disobedience, and delinquency. Early externalizing behaviors are associated with increased risk for a variety of long-term consequences, including academic failure (Arnold, 1997), later socioemotional maladjustment (Campbell et al., 2000; Moffitt, 1993; Moffitt et al., 2002), and poor economic outcomes (Moffitt, 1993; Moffitt et al., 2002), all of which eventually incur high costs to society (Cohen, 1998). The etiology of early externalizing behavior is complex. Some commonly studied factors associated with externalizing behaviors include genes (Rhee & Waldman, 2002; van Hulle et al., 2007), temperament (Campbell et al., 2000; Moffit, 1993), parenting style (McCarty et al., 2005; McLoyd & Smith, 2002; Stormshak et al., 2000), and socioeconomic status (SES; Barry et al., 2005; Murray et al., 2010). Researchers (e.g., Bakermans-Kranenburg et al., 2008; Foley et al., 2004; Propper et al., 2007; Sonuga-Barke et al., 2009; Tucker-Drob & Harden, 2013) are increasingly interested in investigating how individual (e.g., genes, temperament) and social (e.g., parenting, socioeconomic status) risk and protective factors interact to affect the development of externalizing behaviors.

Continuing this integrative approach, the current article focuses on parenting style and SES as factors that may interact with genetic propensities for externalizing behaviors.

[1] Portions of this chapter have been previously published as Cheung, A. K., Harden, K. P., & Tucker-Drob, E. M. (2014). Gene × Environment interactions in early externalizing behaviors: Parental emotional support and socioeconomic context as moderators of genetic influences? *Behavior Genetics*, *44*(5), 468-486.

A number of previous studies have detected gene × parenting and gene × SES interactions on externalizing behaviors; however, the direction of these detected interactions have been inconsistent, with some studies reporting that genes play a less important role at higher level of positive parenting (e.g., DiLalla et al., 2009; Feinberg et al., 2007) or higher SES (e.g., Nobile, et al., 2007), while others reported the opposite pattern (e.g., Brody et al., 2009; Leve et al., 2009; Tuvblad et al., 2006). In the following sections, we first review the extant genetic and socialization literatures on externalizing behaviors, and then describe the utility of a gene × environment interaction approach.

GENETIC AND ENVIRONMENTAL CONTRIBUTIONS

Numerous studies have indicated that externalizing behaviors in childhood are substantially, although not entirely, heritable. For instance, Rhee and Waldman (2002) meta-analyzed 51 twin and adoption studies and found that genes explained an average of 32% of the variance in externalizing behaviors, with environmental factors accounting for the remaining 68%. Environmental influences on externalizing can conceptualized along a continuum ranging from proximal to distal. On the proximal end of the continuum are parents, who act directly upon their children. On the distal end of the continuum is the larger social context. Larger social context does not act directly on children, but instead encompasses collections of proximal environments (e.g., availability of nurturing resources, parenting style of their caregivers, and type of peers they are likely to associate with or be exposed to). In this way, proximal social factors, such as parenting, can be thought of as mediators of more generalized distal social factors, such as SES. However,

because proximal factors encompass collections of very many different proximal factors, it is possible for distal factors to have aggregate effects that differ in direction from the specific effect of an individual proximal factor.

Parental socialization as a protective factor

Emotionally supportive parents can be defined as those who are sensitive to their children's needs, reason with their children, and show their children affection. Through constructive parent-child interactions, parental emotional support is thought to facilitate children's internalization of social values and norms (Patterson et al., 1990) and development of behavioral, cognitive, and emotional self-control (Belsky & Beaver, 2011; Bradley & Corwyn, 2008; Eisenberg et al., 2005; Patterson et al., 1990). For example, children of parents who show high emotional support may learn to be more sensitive to social cues before acting, while children of parents who show low emotional support may act impulsively without regards to social cues. Socially accepted values and skills play an important role in children's psychosocial adjustment (Eisenberg et al., 2001; Eisenberg et al., 2005; Garside & Klimes-Dougan, 2002), and children who are deprived of such socialization have been shown to be at risk for externalizing behaviors (Stormshak et al., 2000; Zimmerman et al., 2005). For example, McLoyd and Smith (2002) followed a group of 4- and 5-year-old children for 6 years and found that higher levels of parental emotional support were associated not only with lower levels of externalizing behaviors at any given time, but also with a slower rate of increase in externalizing behaviors. This protective effect of supportive parents on externalizing development is evident even after

controlling for the initial rate of behavioral problems (Denham et al., 2000) and other biological and contextual variables (McCarty et al., 2005).

Socioeconomic advantage as a protective factor

SES is a widely studied index of the quality of larger social context. Higher SES is consistently associated with lower levels of externalizing behaviors (Barry et al., 2005; Dodge et al., 1994; Keiley et al., 2000; Murray et al., 2010), and this relation is likely to be mediated by more proximal mechanisms. Socioeconomic advantage is not only associated with higher resources, but also with higher quality care provided by individuals in children's immediate environment (Conger et al., 1992; Dodge et al., 1994). Moreover, higher SES parents allocate more time and effort in providing their children a nurturing environment (Kalil et al., 2012). Thus, the effects of SES on externalizing may be partially accounted for by differences in parenting.

GENETIC VULNERABILITY AND RESILIENCE

One mechanism through which early social contexts may influence the development of externalizing behaviors is by modulating the effects of genes on early externalizing behaviors. In other words, one may expect gene × parenting and gene × SES interactions on early externalizing behaviors. However, different theoretical perspectives predict different directions of such interactions. Here, we review three such perspectives.

Diathesis-stress hypothesis

The diathesis-stress hypothesis holds that environmental stressors provide the opportunity for vulnerability genes to be activated (Monroe & Simons, 1991). For example, in a twin study, Feinberg and colleagues (2007) found that genes explained a greater portion of the variance of externalizing behaviors among early adolescents who received less parental warmth. Edwards et al. (2010) found that at higher levels of physically harsh parenting, early adolescents with low MAO-A activity displayed higher levels of externalizing behaviors than those with high MAO-A activity; at lower levels of physically harsh parenting, all adolescents showed similar levels of externalizing behaviors. Foley and colleagues (2004) found similar results when they examined the interaction between MAO-A activity and negative parenting, which was defined by parental neglect, exposure to interparental violence, and inconsistent parental discipline.

Some studies on G × SES interaction in externalizing behaviors have also provided support for the diathesis-stress hypothesis. For example, Nobile and colleagues (2007) observed a higher level of externalizing behaviors only among preadolescents with risk alleles of DRD4 and 5-HTTLPR who were also raised in low SES homes; these alleles were not associated with externalizing behaviors among children raised in higher SES homes.

Social push hypothesis

Raine (2002)'s social push hypothesis predicts a G × E interaction in precisely the opposite direction to that predicted by diathesis-stress hypothesis. This hypothesis holds

that genetic influences on behavioral problems should be most active among individuals situated in minimal risk environments. High risk environments are thought to overwhelm genetic predispositions. In support of this hypothesis, Lahey et al (2008) found that infant temperament, conceptualized as a surrogate for genetic risk, was associated with early conduct problems only for children whose parents showed a higher degree of responsiveness to their needs. Similarly, in a twin study, Button and colleagues (2008) found that genes explained a greater portion of variations in externalizing behaviors among adolescents who received less maternal punitive discipline. Finally, in a twin study, Tuvblad and colleagues (2006) found a greater genetic contribution to externalizing behaviors among adolescents who were raised in higher SES homes than those who were raised in lower SES ones.

Differential susceptibility hypothesis

Instead of conceptualizing genes as conferring risk or vulnerability, the differential susceptibility hypothesis focuses on individual differences in susceptibility to environmental influences (Belsky, 2009; Pluess & Belsky, 2010). Accordingly, individuals with "susceptibility genes" are predicted to be more likely to engage in externalizing behaviors when exposed to contextual adversity but less likely to engage in such behaviors when raised in a nurturing environment. Therefore, this hypothesis predicts that genes have a greater contribution to externalizing behaviors among both individuals exposed to contextual adversities and those exposed to more favorable environments, with the smallest genetic effects in "average" environments. Consistent

with the differential susceptibility hypothesis, Bakermans-Kranenburg and van IJzendoorn (2006) found that preschoolers with DRD4-L displayed more externalizing behaviors when raised by mothers who were insensitive to their needs but fewer externalizing behaviors when raised by mothers who were sensitive to their needs; such association between maternal sensitivity and externalizing behaviors was not observed among preschoolers with DRD4-S. Van Aken and colleagues (2007) observed similar results when they used temperament (i.e., inhibitory control, frustration, activity level, and soothability) as surrogates for genetic risk in a toddler sample.

CURRENT STATUS OF G × E RESEARCH ON THE DEVELOPMENT OF EARLY EXTERNALIZING BEHAVIORS

Despite the fast accumulating evidence for G × E interactions in externalizing behaviors, the actual patterns of interactions obtained have been inconsistent across studies. Given the lack of focus on close replication studies, it is currently unclear whether these differences result from substantively meaningful differences in the genes, environments, and outcomes measured in the different studies. For example, genetic propensities have been indexed by candidate genes, amount of variance explained by a latent genetic factor, matching characteristics in biological parent(s), or infant temperament. Similarly, the operationalization of parenting has included diverse constructs such as sensitivity and physical discipline, and various studies have focused on externalizing behaviors at developmental stages ranging from infancy through early adulthood. It is currently unclear whether G×E interaction effects are robust across

changes in measurement and sampling. Moreover, given social contexts are hardly independent of each other, as in the case of parenting and SES, studying an individual social moderator without accounting for covarying ones might have conflated potentially distinct effects and contributed to the inconsistency across studies. Examining moderation effects of parenting and SES simultaneously and replicating analyses with an independent but comparable sample, as we do in the current study, is therefore one promising attempt to understand the inconsistency in the current G × E literature on externalizing behaviors.

CURRENT STUDY

To address the inconsistency in the current G × E literature on externalizing behaviors, we conducted similar analyses on two genetically informative, longitudinal, population-based datasets. In a first series of models, we individually estimated the moderation effects of parental emotional support and SES on genetic contributions to externalizing development. We then simultaneously examined parenting and SES to investigate their potentially distinct moderation effects.

Methods[2]

PARTICIPANTS

Our first sample was drawn from the Early Child Longitudinal Study – Birth Cohort (ECLS-B), a nationally representative study of the children born in the U.S. in 2001. We used a subsample of approximately[3] 600 twin pairs and their primary caregivers. Data collected when the twins were 4 years old were treated as our time 1 data and those collected when they were 5 years old were treated as our time 2 data. Table I lists the descriptive statistics of our first sample.

Our second sample was drawn from the National Longitudinal Study of Youth 1979 – Children and Young Adults (CNLSY). We used a subsample of 2370 sibling pairs and their biological mothers. The CNLSY sample consists of children born to a nationally representative group of 14- to 22-year-old women who were first surveyed in 1979. Data were collected biennially since 1986 and we used data collected until 2006. Data collected when the children were 4 or 5 years old were treated as our time 1 data and those collected when they were 6 or 7 years old were treated as our time 2 data. Table 1 lists the descriptive statistics of our second sample.

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[2] Portions of this chapter have been previously published as Cheung, A. K., Harden, K. P., & Tucker-Drob, E. M. (2014). Gene × Environment interactions in early externalizing behaviors: Parental emotional support and socioeconomic context as moderators of genetic influences? *Behavior Genetics*, *44*(5), 468-486.

[3] Sample size of our ECLS-B subsample is rounded up to the nearest 50 due to ECLS-B requirements.

	ECLS-B			CNLSY			
	Full Sample	MZ	DZ	Full Sample	FS	HS	US
Age at wave 1 (*M*/*SD*)	4.41/.34	4.40/.34	4.41/.34	5.02/.57; 5.00/.57	5.01/.57; 5.00/.56	5.02/.56; 4.98/.58	5.04/.62; 5.01/.54
Race/Ethnicity (%)							
Caucasian	62.26	56.99	64.48	53.00; 53.00	63.98; 63.98	32.45; 32.45	35.07; 35.07
Latino/ Hispanic	15.61	19.35	14.03	19.96; 19.96	19.97; 19.97	19.30; 19.30	21.80; 21.80
African American	15.76	12.37	17.19	27.00; 27.05	15.98; 16.04	48.26; 48.26	43.13; 43.13
Asian	1.75	3.23	1.13	-	-	-	-
Others	4.62	8.06	3.17	-	-	-	-
Parental Education Level (%)							
< High School	9.55	12.90	8.14	9.08; 12.84	5.14; 7.08	17.01; 23.09	9.50; 18.14
High School	18.79	19.35	18.55	25.20; 32.58	25.69; 32.13	29.89; 40.83	20.09; 26.57
Some College	28.50	31.18	27.38	17.08; 20.60	20.98; 23.74	12.39; 17.38	9.50; 15.33
College or Beyond	43.15	36.56	45.93	19.38; 19.80	27.91; 26.61	4.25; 8.38	4.10; 4.75

Table 1: Sample Statistics. For CNLSY subsample, statistics for sibling 1 are followed by those for sibling 2, separated by a semi-colon.

ECLS-B: Zygosity

Trained observers rated the physical similarity between the twins in each pair on 6 items with a 3-point Likert scale ranging from *No difference* to *Clear difference*. Following the procedures described by Tucker-Drob and colleagues (2011), all items were summed up for each twin pair and this resulted in a bimodal distribution with a range of 6 to 18. Pairs with a sum score of 6 to 8 were classified as MZ twins and the rest were classified as DZ twin pairs. We excluded same-sex DZ twin pairs who had medical reason(s) for their physical dissimilarity. Our final sample consisted of approximately 200 pairs of MZ twins, 200 pairs of same-sex DZ twins, and 250 pairs of opposite-sex DZ twins.

CNLSY: Sibling pairs

For families with more than two children, only the first two were included in our analyses. Following the procedures described by Rodgers and colleagues (1994), each child's household roster provided information for sibling pair assignment. For example, siblings who both lived with their biological father were classified as full-sibling (FS) pairs and pairs in which one lived with biological father while one did not were classified as half-sibling (HS) pairs. Pairs without clear indications were classified as unidentified-sibling (US) pairs. Such assignments resulted in our sample of 736 pairs of same-sex FS, 790 pairs of opposite-sex FS, 1 FS pair without gender information, 290 pairs of same-sex HS, 342 pairs of opposite-sex HS, 94 pairs of same-sex US, and 117 pairs of opposite-sex US.

MEASURES

ECLS-B: Parental emotional support

Trained coders rated on the degree of each primary caregiver's "emotional availability and physical and affective presence" (Najarian et al., 2010, p. 120) to the child during a 10-minute semi-structured task called the Two Bags Task. According to the ECLS-B Psychometric Report (Najarian et al., 2010), parental emotional support is defined as "(1) providing a secure base from which the child can explore, and (2) displaying emotional support and enthusiasm for the child and his or her autonomous work" (p. 120). The Two Bags Task was adapted from the Three Bags Task used in the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development. Parents were asked to read a storybook to and use Play-Doh with each of their children. The administration order of these two tasks was counterbalanced and the entire interaction for each dyad was recorded. Using these video-recordings, trained coders rated each parent's emotional supportiveness on a 7-point Likert scale ranging from *very low* to *very high*. Inter-rater reliability among the 13 trained coders was 90.8% (Najarian et al., 2010).

CNLSY: Parental emotional support

Using the Home Observation Measurement of Environment – Short Form (HOME-SF), parents and trained interviewers rated different parenting items that were then grouped to create the emotional support subscale. The HOME-SF (see Menaghan & Parcel, 1991 and Mott, 2004 for reliability and utility information) was adapted from the

HOME Inventory (Bradley et al., 1996; Bradley et al., 1994). Questions for parents included "how often do you talk to child while you are working?" and those for trained interviewers included "mother caressed, kissed, or hugged child at least once?" Each item was recoded using a dichotomous scale with higher score indicating higher level of parental emotional support. Composite scores were then standardized with respect to the full CNLSY sample to have a mean of 100 and a standard deviation of 15.

ECLS-B: Socioeconomic status

A composite score on SES was calculated using household income and three other pieces of information on both male and female primary caregivers of each child: highest completed level of education, labor force status (i.e., working or not), and occupational prestige. Composite scores were standardized with respect to the full ECLS-B sample to have a mean of 0 and a standard deviation of 1.

CNLSY: Socioeconomic status

Total family income was used as a proxy of SES. It included government support and food stamps but excluded income of cohabitating partner who was not married to the child's biological mother. Because data were collected over the course of 20 years, total family income of each child was adjusted to 2008 dollars using the consumer price index listed on the website of Integrated Public Use Microdata Series – Current Population Survey (University of Minnesota, Minnesota Population Center, n.d.).

ECLS-B: Externalizing behaviors

The sum score on four items from the Preschool and Kindergarten Behavioral Scale – 2nd Edition (see Edwards, 2009 and Riccio, 1995 for reliability and validity information) and one item from the Social Skills Rating System (see Van Horn et al., 2007 for reliability and validity information) was used to reflect the level of externalizing behaviors each child displayed. Primary caregivers rated each twin's behaviors on a 5-point Likert scale ranging from 1=*Never* to 5=*Very Often*. Sample items include "child is physically aggressive" and "child has temper tantrums." For our sample, Cronbach's alpha of these 5 items is .73 for twin 1 at time 1, .79 for twin 2 at time 1, .81 for twin 1 at time 2, and .80 for twin 2 at time 2.

CNLSY: Externalizing behaviors

The average score on nine items from the Behavioral Problem Index (BPI; see Peterson & Zill, 1986 for more information on the creation of this index) was used to reflect the level of externalizing behaviors each child displayed. BPI was adapted from the widely used Child Behavior Checklist (CBCL; Achenbach, 2012). Mothers rated on each child's behaviors on a 3-point Likert Scale ranging from 0=*Often True* to 2=*Not True*. Sample items include "bullies or is cruel/mean to others" and "has strong temper and loses it easily." For our sample, Cronbach's alpha is .77 at time 1 and .79 at time 2. Table 2 compares the items used to measure externalizing behaviors across our ECLS-B and CNLSY subsamples.

ECLS-B	CNLSY
	Cheats or tells lies
	Argues too much
Child is physically aggressive	Bullies or is cruel/mean to others
	Is disobedient at home
	Is stubborn, sullen, or irritable
Child has temper tantrums	Has strong temper and loses it easily
Child destroys others' things	Breaks things deliberately
	Is disobedient at school
	Has trouble getting along with teachers
Child is angry	
Child annoys other children	

Table 2: Comparison of items used in measuring externalizing behaviors. Items that are similar to each other across samples are listed side-by-side.

DATA ANALYSES

Data were transformed and standardized prior to model fitting. Table 3 lists the skewness statistics of these variables before and after data transformation. Scores on externalizing behaviors in both samples and SES of the CNLSY subsample were substantially positively skewed and were log transformed to have near normal distributions. Scores on parental emotional support of the CNLSY subsample were also somewhat positively skewed and were square-root transformed to have a near normal distribution. We then z-transformed each variable based on the mean and standard deviation observed for that variable in sibling 1 at time 1.

	Skewness/*SE*			
	ECLS-B		CNLSY	
	Before	After	Before	After
$EMOSUP_{1,1}$	-	-	-.73/.05	-.06/.05
$EMOSUP_{1,2}$	-	-	-.73/.05	-.04/.05
$SES_{1,1}$	-	-	9.25/.06	-4.06/.06
$SES_{1,2}$	-	-	9.00/.06	-4.12/.06
$EXT_{1,1}$	.46/.10	-.38/.10	.84/.07	.29/.07
$EXT_{1,2}$	.75/.10	-.20/.10	.96/.06	.40/.06
$EXT_{2,1}$	.72/.11	-.19/.11	1.05/.06	.50/.06
$EXT_{2,2}$	.66/.11	-.21/.11	1.09/.05	.52/.05

Table 3: Skewness Statistics of Variables before and after Transformations. EMOSUP = parental emotional support. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair.

We then fit three structural equation models to each of our samples using maximum likelihood estimation in *Mplus* statistical software (Muthén & Muthén, 2010) to investigate the moderation effects of parental emotional support and SES on genetic and environmental contributions to externalizing behaviors. *Mplus* uses Full-information Maximum Likelihood method to handle missing data, except when the missingness is on the moderator, in which case *Mplus* does not allow for missingness and excludes such cases from analyses. In our model with only parental emotional support as the moderator, 15% of the ECLS-B subsample and 13% of the CNLSY subsample were excluded due to missingness on the moderator. In our model with only SES as the moderator, 0% of the ECLS-B subsample and 41% of the CNLSY subsample were excluded due to missingness on SES. In our final model with both parental emotional support and SES as moderators, 15% of the ECLS-B subsample and 53% of the CNLSY subsample were excluded due to missingness on either moderator.

For parental emotional support at time 1 and externalizing behaviors at both times, variance was modeled as a linear function of additive genes (*A*), shared environment (*C*), and non-shared environment (*E*). For ECLS-B data, corresponding *A*'s were constrained to correlate at 1.0 for MZ twin pairs and 0.5 for DZ twin pairs. For CNLSY data, corresponding *A*'s were constrained to correlate at .5 for FS pairs, .25 for HS pairs, and .375 for US pairs. *C*'s represent all environmental factors that contribute to the similarity between siblings in a pair and therefore corresponding *C*'s were constrained to correlate at 1.0 for all sibling pairs. Because *E*'s represent environmental factors that contribute to the dissimilarity between siblings in a pair and all measurement errors,

corresponding *E*'s were independently estimated for all sibling pairs. All corresponding regression coefficients were constrained to be the same for all siblings in each model. Figure 1 illustrates our longitudinal Cholesky model. We investigated whether moderation effect(s) observed would act on the genetic and environmental influences at time 1 (i.e., the paths from A_1, C_1, and E_1 to externalizing behaviors at time 1), those carried-over from time 1 to externalizing behaviors at time 2 (i.e., the paths from A_1, C_1, and E_1 to externalizing behaviors at time 2), and/or those unique to externalizing behaviors at time 2 (i.e., the paths from A_2, C_2, and E_2 to externalizing behaviors at time 2).

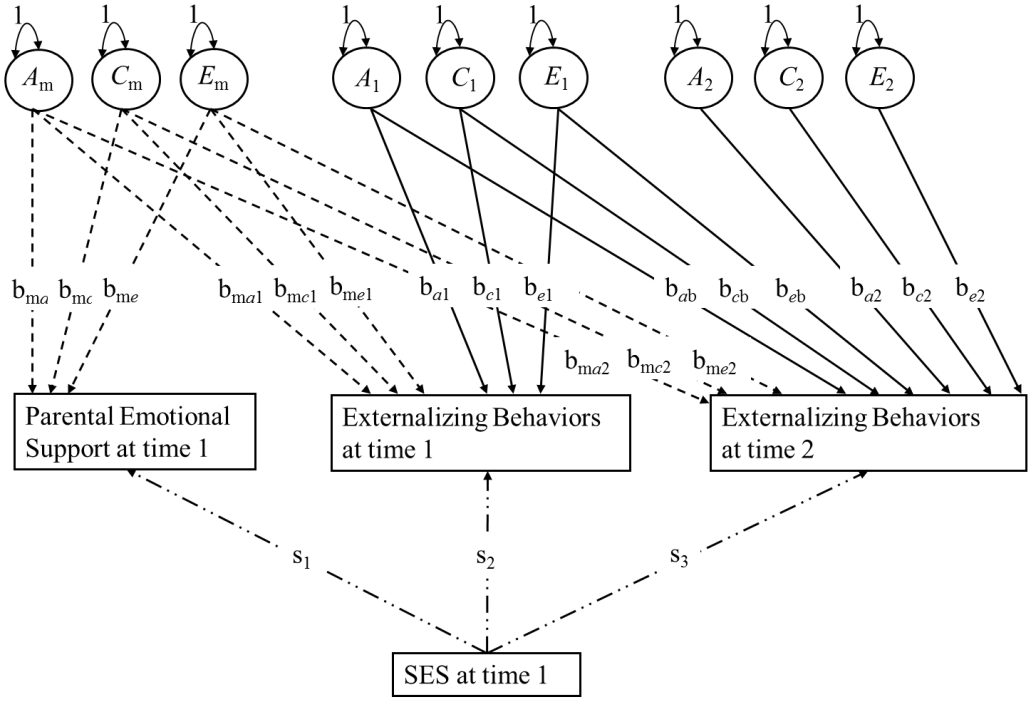

Figure 1: A longitudinal Cholesky model of externalizing behaviors measured at 2 time points, controlling for the main effect(s) of moderator(s). Only the part for one sibling from each pair is presented. This path diagram illustrates the models we fit to our ECLS-B subsample. The same models were fit to our CNLSY subsample, except SES was modeled as two observed variables, one per sibling in a pair, because the assessment year when a sibling reached 4 or 5 years old is different from that when the other one in the pair reached the same age. Parts with solid lines and evenly broken lines illustrate model 1. Paths b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2} in model 1 each contains a main effect (i.e., b_{a10}, b_{c10}, b_{e10}, b_{ab0}, b_{cb0}, b_{eb0}, b_{a20}, b_{c20}, and b_{e20}) and an interaction with parental emotional support (i.e., b_{a1}', b_{c1}', b_{e1}', b_{ab}', b_{cb}', b_{eb}', b_{a2}', b_{c2}', and b_{e2}'). Parts with solid lines and unevenly broken lines illustrate model 2. Paths b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2} in model 2 each contains a main effect (i.e., b_{a10}, b_{c10}, b_{e10}, b_{ab0}, b_{cb0}, b_{eb0}, b_{a20}, b_{c20}, and b_{e20}) and an interaction with socioeconomic status (i.e., b_{a1}', b_{c1}', b_{e1}', b_{ab}', b_{cb}', b_{eb}', b_{a2}', b_{c2}', and b_{e2}'). The whole figure illustrates our final model with both moderators. Paths b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2} in model 3 each contains a main effect (i.e., b_{a10}, b_{c10}, b_{e10}, b_{ab0}, b_{cb0}, b_{eb0}, b_{a20}, b_{c20}, and b_{e20}) and two interactions, one with parental emotional support (i.e., b_{a1}', b_{c1}', b_{e1}', b_{ab}', b_{cb}', b_{eb}', b_{a2}', b_{c2}', and b_{e2}') and one with socioeconomic status (i.e., b_{a1}'', b_{c1}'', b_{e1}'', b_{ab}'', b_{cb}'', b_{eb}'', b_{a2}'', b_{c2}'', and b_{e2}'').

In our first model (see Figure 1), we controlled for the main effect of parental emotional support on externalizing behaviors by regressing externalizing behaviors at both times on *A*, *C*, and *E* of parental emotional support. *A*'s, *C*'s, and *E*'s of externalizing behaviors therefore reflect genetic and environmental contributions that are above and beyond the effect of parental emotional support. To examine the moderation effect of parental emotional support, effects of *A*'s, *C*'s, and *E*'s on externalizing behaviors were allowed to vary as a function of parental emotional support. Each of the nine regression paths (i.e., b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2}) of externalizing behaviors contains a main effect (i.e., b_{a10}, b_{c10}, b_{e10}, b_{ab0}, b_{cb0}, b_{eb0}, b_{a20}, b_{c20}, and b_{e20}) and an interaction with parental emotional support (i.e., b_{a1}', b_{c1}', b_{e1}', b_{ab}', b_{cb}', b_{eb}', b_{a2}', b_{c2}', and b_{e2}'). A statistically significant interaction suggests a moderation effect of parental emotional support on the corresponding factor. For instance, if b_{a2}' is statistically significant, it suggests that the influence of A_2 (i.e., additive genes unique to time 2) on time 2 externalizing behaviors differs by the amount of parental emotional support a child received.

Our second model was similar to our first one except parental emotional support was replaced with SES (see Figure 1). Because SES provides information on the socioeconomic difference between families rather than siblings, we did not decompose the variance of SES in our models. For the ECLS-B subsample, SES was modeled as a single observed variable per pair of twins because it was measured at the family level at the same time for each twin. For the CNLSY subsample, SES was modeled as two observed variables, one per sibling in a pair, because the assessment year when a sibling

reached 4 or 5 years old is different from that when the other one in the pair reached the same age. Similar to our first model, each of the nine regression paths (i.e., b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2}) of externalizing behaviors contains a main effect (i.e., b_{a10}, b_{c10}, b_{e10}, b_{ab0}, b_{cb0}, b_{eb0}, b_{a20}, b_{c20}, and b_{e20}) and an interaction with SES (i.e., b_{a1}', b_{c1}', b_{e1}', b_{ab}', b_{cb}', b_{eb}', b_{a2}', b_{c2}', and b_{e2}'). A statistically significant interaction term in our second model suggests a moderation effect of SES on the corresponding factor.

In our third model, we simultaneously included both parental emotional support and SES as moderators to investigate their independent effects on genetic and environmental influences on externalizing behaviors (see Figure 1). In this final model, each of the nine regression paths (i.e., b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2}) of externalizing behaviors contained a main effect and two interaction terms, one with parental emotional support and one with SES. If any of the interactions with parental emotional support in this model is statistically significant, this suggests that parental emotional support moderates the influence of that corresponding latent factor in externalizing behaviors above and beyond the effects of SES. Similarly, if any of the interactions with SES in this model is statistically significant, this suggests that SES moderates the influence of that corresponding latent factor in externalizing behaviors above and beyond the effects of parental emotional support.

Results[4]

Table 4 lists the descriptive statistics of the two moderators and externalizing behaviors at both times before standardization with respect to our samples and Tables 5 and 6 list the correlation coefficients of these variables. Correlation coefficients obtained from the CNLSY subsample were more consistent with the relation between parental socialization and externalizing behaviors discussed earlier than those from the ECLS-B subsample. For the CNLSY subsample, parental emotional support was positively correlated with SES and both of these factors were negatively correlated with externalizing behaviors at both times. Similar observations were obtained from the ECLS-B subsample, except that parental emotional support was not significantly correlated with externalizing behaviors measured at either time point. For both samples, scores on externalizing behaviors were positively correlated across siblings and across times.

[4] Portions of this chapter have been previously published as Cheung, A. K., Harden, K. P., & Tucker-Drob, E. M. (2014). Gene × Environment interactions in early externalizing behaviors: Parental emotional support and socioeconomic context as moderators of genetic influences? *Behavior Genetics*, *44*(5), 468-486.

	ECLS-B (*M*/*SD*/N)			CNLSY (*M*/*SD*/N)			
	Full Sample	MZ	DZ	Full Sample	FS	HS	US
$EMOSUP_{1,1}$	4.53/.95/ 550	4.51/.93/ 150	4.54/.96/ 400	100.12/14.00/ 2177	103.50/12.30/ 1400	94.38/15.12/ 606	92.82/13.55/ 171
$EMOSUP_{1,2}$	4.52/.96/ 550	4.53/.90/ 150	4.52/.98/ 400	97.95/14.39/ 2126	101.50/12.57/ 1350	91.81/15.48/ 596	91.68/14.55/ 180
$SES_{1,1}$	.12/.85/600	-.02/.88/200	.18/.83/450	66008.09/ 110381.40/ 1528	78158.99/ 126150.60/ 1098	34263.19/ 37086.55/ 309	36813.77/ 35019.11/ 121
$SES_{1,2}$				66489.75/ 115798.65/ 1955	80436.93/ 133675.10/ 1281	40815.22/ 67950.57/ 507	37451.78/ 40249.01/ 167
$EXT_{1,1}$	11.68/3.10/ 600	11.64/3.32/ 200	11.69/3.01/ 450	.42/.32/1278	.40/.31/938	.47/.34/248	.53/.34/92
$EXT_{1,2}$	11.80/3.37/ 600	11.82/3.09/ 200	11.80/3.48/ 450	.42/.35/1604	.39/.33/1040	.48/.38/443	.43/.34/121
$EXT_{2,1}$	11.36/3.39/ 500	11.12/3.13/ 150	11.46/3.49/ 350	.36/.30/1914	.34/.29/1309	.40/.33/455	.43/.35/150
$EXT_{2,2}$	11.22/3.38/ 500	11.01/3.21/ 150	11.30/3.45/ 350	.37/.33/2050	.35/.31/1326	.41/.35/558	.45/.34/166

Table 4: Descriptive Statistics of Variables. EMOSUP = parental emotional support. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair. Ns for our ECLS-B subsample are rounded up to the nearest 50s due to ECLS-B requirements.

	$EMOSUP_{1,1}$	$EMOSUP_{1,2}$	SES_1	$EXT_{1,1}$	$EXT_{1,2}$	$EXT_{2,1}$
$EMOSUP_{1,2}$	.55** (.57**/.55**)	-				
SES_1	.41** (.35**/.45**)	.35** (.32**/.37**)	-			
$EXT_{1,1}$	-.06 (-.07/-.06)	-.07^ (-.10/-.06)	-.09* (-.09/-.09^)	-		
$EXT_{1,2}$	<.01 (-.03/.01)	-.06 (-.14^/-.03)	-.12** (-.16*/-.11*)	.45** (.61**/.39**)	-	
$EXT_{2,1}$	-.05 (-.13/-.03)	-.08^ (-.10/-.07)	-.16** (-.22**/-.14**)	.57** (.50**/.60**)	.26** (.46**/.19**)	-
$EXT_{2,2}$	<-.01 (-.04/.01)	-.04 (.01/-.06)	-.10* (-.10/-.11*)	.33** (.43**/.29**)	.61** (.56**/.62**)	.43** (.65**/.36**)

Table 5: Correlation between Variables Observed with ECLS-B Sample. EMOSUP = parental emotional support. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair. SES was measured only once at wave 1 because the twins reached the same age at the same time. ^ $p < .10$. * $p < .05$. ** $p < .01$. Estimates outside brackets are for the whole sample. The first estimate in each bracket is the one for MZ twins and the second one is the one for DZ twins.

	$EMOSUP_{1,1}$	$EMOSUP_{1,2}$	$SES_{1,1}$	$SES_{1,2}$	$EXT_{1,1}$	$EXT_{1,2}$	$EXT_{2,1}$
$EMOSUP_{1,2}$	.62** (.64**/ .50**/.54**)	-					
$SES_{1,1}$	.12** (.05^/ .22**/.10)	.09** (.02/ .19**/.21*)	-				
$SES_{1,2}$	.18** (.12**/ .22**/.20*)	.17** (.11**/ .20**/.32**)	.29** (.26**/ .64**/.42**)	-			
$EXT_{1,1}$	-.19** (-.13**/ -.20*/-.22^)	-.17** (-.15**/ -.07/-.11)	-.13** (-.12**/ -.17**/.01)	-.10** (-.09**/ -.15*/-.06)	-		
$EXT_{1,2}$	-.15** (-.15**/ -.13**/.07)	-.16** (-.17**/ -.09^/-.03)	-.08* (-.10/ -.10/.05)	-.05^ (-.05/ -.02/-.09)	.28** (.30**/ .17*/.31*)	-	
$EXT_{2,1}$	-.15** (-.17**/ -.09^/.05)	-.14** (-.14**/ -.09^/.07)	-.12** (-.09**/ -.09/-.04)	-.08** (-.06*/ -.12*/-.16^)	.56** (.57**/ .50**/.57**)	.37** (.38**/ .33**/.37**)	-
$EXT_{2,2}$	-.16** (-.14**/ -.17**/-.01)	-.17** (-.14**/ -.16**/-.12)	-.10** (-.10**/ -.10^/.20^)	-.08** (-.08**/ -.01/-.10)	.27** (.29**/ .18**/.13)	.59** (.58**/ .62**/.44**)	.30** (.32**/ .28**/.11)

Table 6: Correlation between Variables Observed with CNLSY Sample. EMOSUP = parental emotional support. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair. ^ $p < .10$. * $p < .05$. ** $p < .01$. Estimates outside brackets are for the whole sample. The first estimate in each bracket is for full-sibling pairs, the second one is for half-sibling pairs, and the third one is for unidentified-sibling pairs.

The main goal of the current study is to investigate moderation effects of parental emotional support and SES on the genetic and environmental influences on externalizing behaviors over time. We therefore focus our attention on the nine regression paths described above (i.e., b_{a1}, b_{c1}, b_{e1}, b_{ab}, b_{cb}, b_{eb}, b_{a2}, b_{c2}, and b_{e2}; see Figure 1). Tables 7 through 9 report both main effect and interaction parameter estimates for these nine paths, obtained from our three models for both samples. These results are derived from models that did not estimate what might be described as moderated covariances (quasi-quadratic effects) between each moderator and each outcome variable. Thus we estimated 9 interactions in models with a single moderator and 18 interactions in models with both parental emotional support and SES as moderators. As van der Sluis and colleagues (2012) have explicated, failing to model a moderated covariance between a moderator and a phenotype, if one truly exists, can lead to false positive results in other portions of the model. While we appreciate this point, we also note that estimating these additional interactions in the, already complex, longitudinal model that we have adopted may (ironically) inflate the risk for false positive results due to increased multiple hypothesis testing and model over-fitting. We believe that the less complex models that do not include moderated covariances between moderators and phenotypes may therefore be less prone to over-fitting and be more likely to replicate across samples. As we make a particular point of the issue of replicability, we therefore choose to report the results from these less complex models in the body of this paper. In the Appendix, we report results from the more complex models with moderated covariances between moderators and phenotypes. Importantly, our primary conclusion remains unaltered across modeling

choices: the interactions detected in the ECLS-B sample do not replicate in the CNLSY sample.

	ECLS-B		CNLSY	
Path	Main Effect	Interaction	Main Effect	Interaction
b_{a1}	**.78(±.16)**	-.06 (±.12)	**.62(.29)**	.10 (±.12)
b_{c1}	.19(±.32)	**.25 (±.12)**	**.44(.19)**	-.07 (±.10)
b_{e1}	**.51(±.06)**	-.07 (±.08)	**.67(.42)**	.05 (±.08)
b_{ab}	**.58(±.34)**	-.02 (±.12)	**.58(.27)**	-.08 (±.10)
b_{cb}	.19(±.27)	.01 (±.16)	**.41(.17)**	.07 (±.08)
b_{eb}	**.16(±.09)**	.06 (±.14)	.11(.40)	.06 (±.10)
b_{a2}	**.43(±.33)**	**-.17 (±.18)**	-	-
b_{c2}	.28(±.29)	-.07 (±.20)	-	-
b_{e2}	**.53(±.06)**	-.02 (±.06)	**.71(.10)**	**.12 (±.06)**

Table 7: Main Effect and Interaction Parameter Estimates in Model 1 (Parental Emotional Support at Time 1 as Moderator). Bolded = $p < .05$. In the model fitted to CNLSY data, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

	ECLS-B		CNLSY	
Path	Main Effect	Interaction	Main Effect	Interaction
b_{a1}	**.61(±.16)**	**.17 (±.10)**	**.79(±.30)**	-.04 (±.14)
b_{c1}	**.45(±.18)**	**-.17 (±.12)**	.28(±.40)	-.04 (±.20)
b_{e1}	**.62(±.06)**	**-.08 (±.04)**	**.62(±.22)**	-.08 (±.12)
b_{ab}	**.83(±.15)**	-.07 (±.12)	**.73(±.26)**	-.07 (±.10)
b_{cb}	.07(±.28)	-.02 (±.18)	.24(±.35)	-.01 (±.14)
b_{eb}	**.19(±.09)**	-.06 (±.08)	-.06(±.40)	.02 (±.12)
b_{a2}	.15(±.33)	**.26 (±.18)**	.00(±.24)	<.01 (±.16)
b_{c2}	.24(±.37)	-.04 (±.24)	.00(±.15)	<.01 (±.16)
b_{e2}	**.58(±.06)**	-.05 (±.06)	**.66(±.21)**	-.05 (±.10)

Table 8: Main Effect and Interaction Parameter Estimates in Model 2 (SES at Time 1 as Moderator). Bolded = $p < .05$.

Path	ECLS-B			CNLSY		
		Interaction			Interaction	
	Main Effect	Parental Emotional Support	SES	Main Effect	Parental Emotional Support	SES
b_{a1}	**.73(±.15)**	.06 (±.10)	**.12 (±.10)**	**.76(±.26)**	.04 (±.10)	.01 (±.14)
b_{c1}	**.33(±.25)**	-.11 (±.14)	-.11 (±.16)	.30(±.30)	-.02 (±.14)	-.12 (±.18)
b_{e1}	**.52(±.06)**	-.06 (±.08)	**-.07 (±.06)**	**.61(±.21)**	.04 (±.10)	-.09 (±.14)
b_{ab}	**.78(±.19)**	-.07 (±.12)	-.04 (±.12)	**.70(±.22)**	-.03 (±.12)	-.08 (±.10)
b_{cb}	-.08(±.32)	.01 (±.18)	-.04 (±.20)	.24(±.27)	.12 (±.12)	.03 (±.16)
b_{eb}	**.11(±.08)**	.02 (±.12)	-.01 (±.08)	-.04(±.36)	.06 (±.14)	.04 (±.16)
b_{a2}	.07(±.39)	.07 (±.18)	**.24 (±.16)**	-	-	-
b_{c2}	.24(±.33)	-.16 (±.18)	.04 (±.25)	-	-	-
b_{e2}	**.53(±.06)**	-.01 (±.06)	-.05 (±.06)	**.65(±.36)**	**.09 (±.08)**	<.01 (±.12)

Table 9: Main Effect and Interaction Parameter Estimates in Model 3 (Two Moderators). Bolded = $p < .05$. In the model fitted to CNLSY data, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

MODEL 1: PARENTAL EMOTIONAL SUPPORT

Given the protective effect of parental socialization and existing findings summarized above, we anticipated that the importance of genes and environmental factors in externalizing behaviors would vary by the amount of parental emotional support a child received. With a longitudinal Cholesky model, we also explored if parental emotional support would moderate genetic and environmental influences on externalizing behaviors at time 1, those carried over from time 1 on externalizing behaviors at time 2, and/or those unique to time 2. Figure 2 contains four panels for results comparison across samples and across times, with each panel illustrating results observed for one sample at one time point.

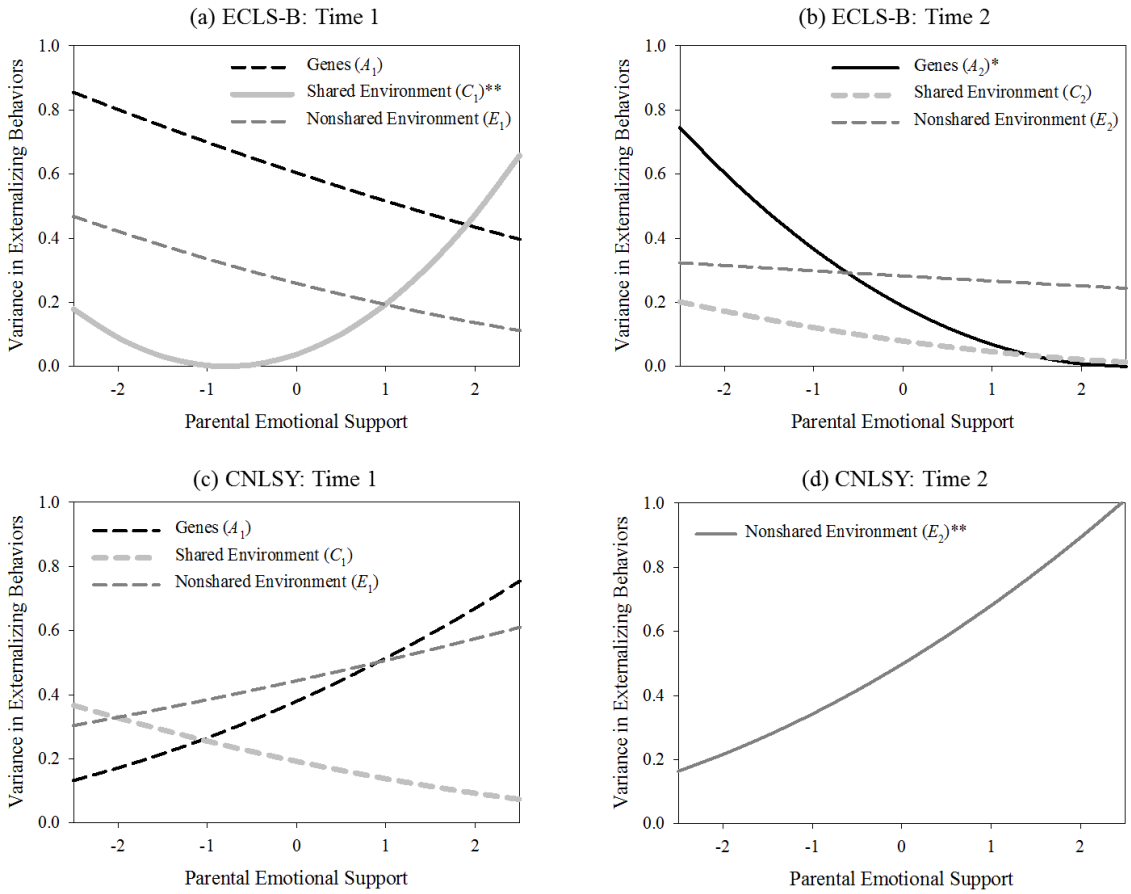

Figure 2: Graphic representation of interactions observed from model 1 (i.e., moderation effects of parental emotional support). Upper panels illustrate results from the ECLS-B subsample while lower panels illustrate results from the CNLSY subsample. Left panels illustrate genetic and environmental influences at time 1 while right panels illustrate genetic and environmental influences that were unique to time 2. Black lines represent genetic influences, light grey lines represent shared environmental influences, and dark grey lines represent non-shared environmental influences. Solid lines indicate statistically significant G × E interactions. * $p < .05$. ** $p < .01$. Dashed lines indicate statistically insignificant ones. For the CNLSY subsample, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

ECLS-B

Our model fit the ECLS-B data well (model fit statistics from main effect model: $\chi^2(33) = 27.490$, $p = .738$, RMSEA < .001, CFI = 1.000, TLI = 1.006). At time 1, shared environment influenced externalizing behaviors differentially by levels of parental emotional support. C_1 accounted for 9% of the variance of time 1 externalizing behaviors among children who received parental emotional support that was 2*SD* below sample average but for 47% among those who received parental emotional support that was 2*SD* above sample average (see upper left panel of Figure 2). While influence of shared environment differed by levels of parental emotional support, genes were more influential than environmental factors at time 1 ($a^2 = 60\%$, $e^2 = 26\%$) and the importance of A_1 and E_1 in externalizing behaviors remained constant at all levels of parental emotional support. In contrast, A_2 influenced externalizing behaviors differentially by levels of parental emotional support. A_2 accounted for 60% of the variance of time 2 externalizing behaviors among children who received parental emotional support that was 2*SD* below sample average but for 0% among those who received parental emotional support that was 2*SD* above sample average (see upper right panel of Figure 2). Environmental influences unique to time 2 remained constant ($c^2 = 8\%$, $e^2 = 28\%$) regardless of the amount of parental emotional support a child received. Relation of externalizing behaviors across the two time points was mediated by genes. Of the total variance of time 2 externalizing behaviors, 34% was explained by A_1 and none was explained by C_1 and E_1; and these carried-over influences remained constant regardless of the amount of parental emotional support a child received.

CNLSY

None of the interactions observed for the ECLS-B subsample was replicated using the CNLSY subsample (model fit statistics from main effect model: $\chi^2(62) = 592.764$, $p < .001$, RMSEA = .091, CFI = .782, TLI = .842). Externalizing behaviors at time 1 was mostly influenced by A_1 and E_1 (a^2 = 38%, c^2 = 19%, e^2 = 44%), and these genetic and environmental influences at time 1 remained constant at all levels of parental emotional support. The only statistically significant interaction was observed at time 2. E_2 accounted for 22% of the variance of time 2 externalizing behaviors among children who received parental emotional support that was 2*SD* below sample average but for 89% among those who received parental emotional support that was 2*SD* above sample average (see lower right panel of Figure 2). This moderation effect of parental emotional support on the influence of E_2 was not observed for the ECLS-B subsample. Results from the main effect model suggest that A_2 and C_2 have no effect on externalizing behaviors and E_2 is therefore the sole latent factor in time 2 externalizing behaviors, above and beyond the main effects of parental emotional support and influences carried-over from time 1. Similar to results observed for the ECLS-B subsample, relation of externalizing behaviors across the two time points was mediated more by genes than environments. Of the total variance of time 2 externalizing behaviors, 33% was explained by A_1, 16% was explained by C_1, and 1% was explained by E_1; and these carried-over influences remained constant regardless of the amount of parental emotional support a child received.

MODEL 2: SES

Using the longitudinal Cholesky model outlined above, we also examined if SES would moderate genetic and environmental influences on externalizing behaviors at time 1, those carried over from time 1 onto externalizing behaviors at time 2, and/or those unique to time 2. Figure 3 contains four panels for results comparison across samples and across times, with each panel illustrating results observed for one sample at one time point.

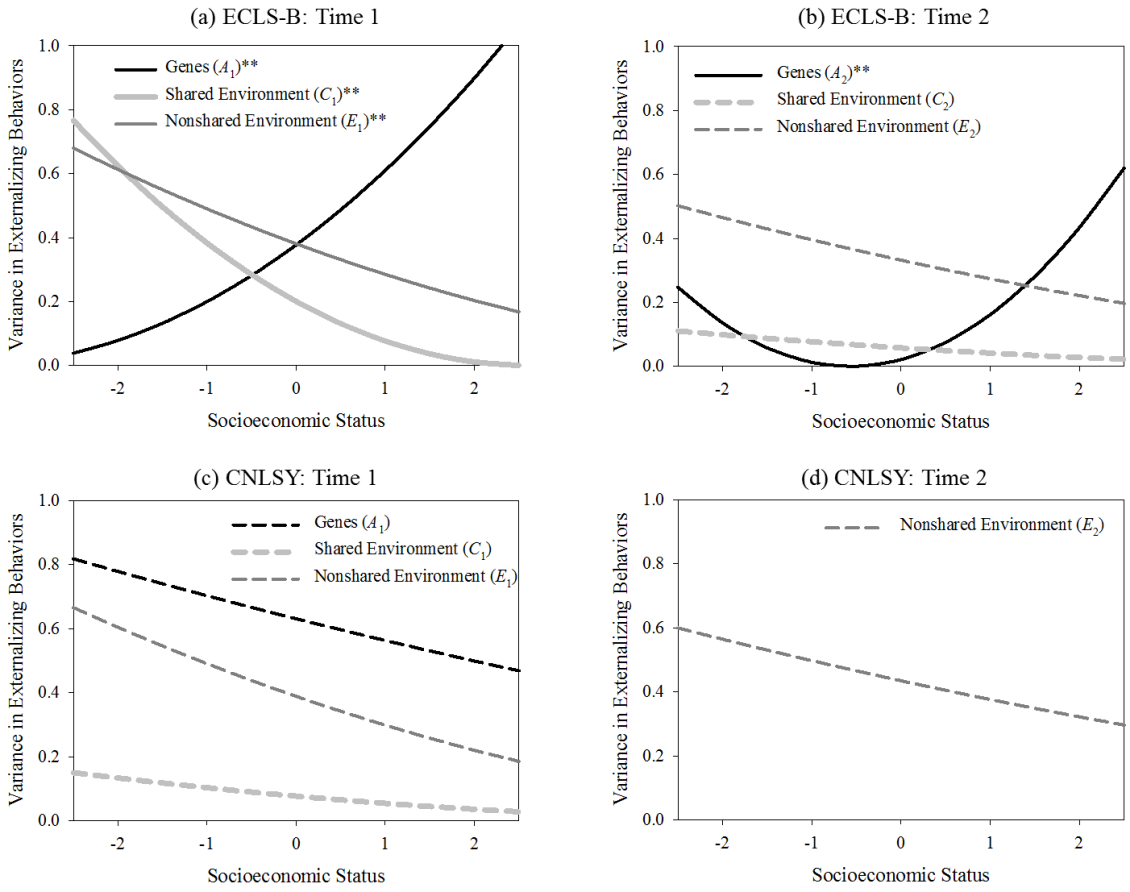

Figure 3: Graphic representation of interactions observed from model 2 (i.e., moderation effects of socioeconomic status). Upper panels illustrate results from the ECLS-B subsample while lower panels illustrate results from the CNLSY subsample. Left panels illustrate genetic and environmental influences at time 1 while right panels illustrate genetic and environmental influences that were unique to time 2. Black lines represent genetic influences, light grey lines represent shared environmental influences, and dark grey lines represent non-shared environmental influences. Solid lines indicate statistically significant G × E interactions. * $p < .05$. ** $p < .01$. Dashed lines indicate statistically insignificant ones.

ECLS-B

Our model fit the ECLS-B data well (model fit statistics from main effect model: $\chi^2(23) = 24.604$, $p = .371$, RMSEA = .015, CFI = .998, TLI = .998). At time 1, influence of genes became more important while that of environments became less at higher SES. Externalizing behaviors at time 1 was more influenced by C_1 and E_1 ($a^2 = 8\%$, $c^2 = 62\%$, $e^2 = 61\%$) among children from families whose SES was 2*SD* below the sample average but more by A_1 ($a^2 = 90\%$, $c^2 = 1\%$, $e^2 = 20\%$) among those from families whose SES was 2*SD* above the sample average (see upper left panel of Figure 3). A similar $A\times$ SES interaction was also observed at time 2. A_2 accounted for 14% of the variance of time 2 externalizing behaviors among children from families whose SES was 2*SD* below the sample average but for 43% among children from families whose SES was 2*SD* above the sample average (see upper right panel of Figure 3). While A_2 influenced time 2 externalizing behaviors differentially by levels of SES, influences of C_2 and E_2 remained constant ($c^2 = 6\%$, $e^2 = 33\%$) regardless of the level of SES. Similar to results from model 1, relation of externalizing behaviors across the two time points was mediated mostly by genes. Of the total variance of time 2 externalizing behaviors, 68% was explained by A_1, 0% was explained by C_1, and 4% was explained by E_1; and these carried-over influences remained constant at all levels of SES.

CNLSY

None of the SES interactions observed for the ECLS-B subsample was replicated using the CNLSY subsample (see lower panels of Figure 3; model fit statistics from main

effect model: $\chi^2(51) = 153.258$, $p <. 001$, RMSEA = .044, CFI = .931, TLI = .943). With CNLSY data, SES did not interact with any of the genetic and environmental factors in externalizing behaviors. Externalizing behaviors at time 1 were influenced mostly by A_1 and E_1 (a^2 = 63%, c^2 = 8%, e^2 = 39%) and these genetic and environmental influences at time 1 remained constant at all levels of SES. At time 2, E_2 explained 43% of the variance of externalizing behaviors at all levels of SES. Consistent with observations from analyses on ECLS-B data, relation of externalizing behaviors across the two time points was mediated mostly by genes. Of the total variance of time 2 externalizing behaviors, 54% was explained by A_1, 6% was explained by C_1, and 0% was explained by E_1; and these carried-over influences remained constant regardless of the level of SES.

MODEL 3: PARENTAL EMOTIONAL SUPPORT AND SES

Since parental emotional support and SES are positively correlated with each other and both are commonly studied factors in externalizing behaviors, differentiating their moderation effects on genetic and environmental influences on externalizing behaviors might help understand the complex etiology of behavioral maladjustment. To do this, we simultaneously included both parental emotional support and SES as moderators in our final model and examined if they had distinct moderation effects on genetic and environmental influences on externalizing behaviors. Figures 4 and 5 illustrate results on the independent moderation effects of parental emotional support and SES respectively. Each figure contains four panels for results comparison across samples

and across times, with each panel illustrating results observed for one sample at one time point.

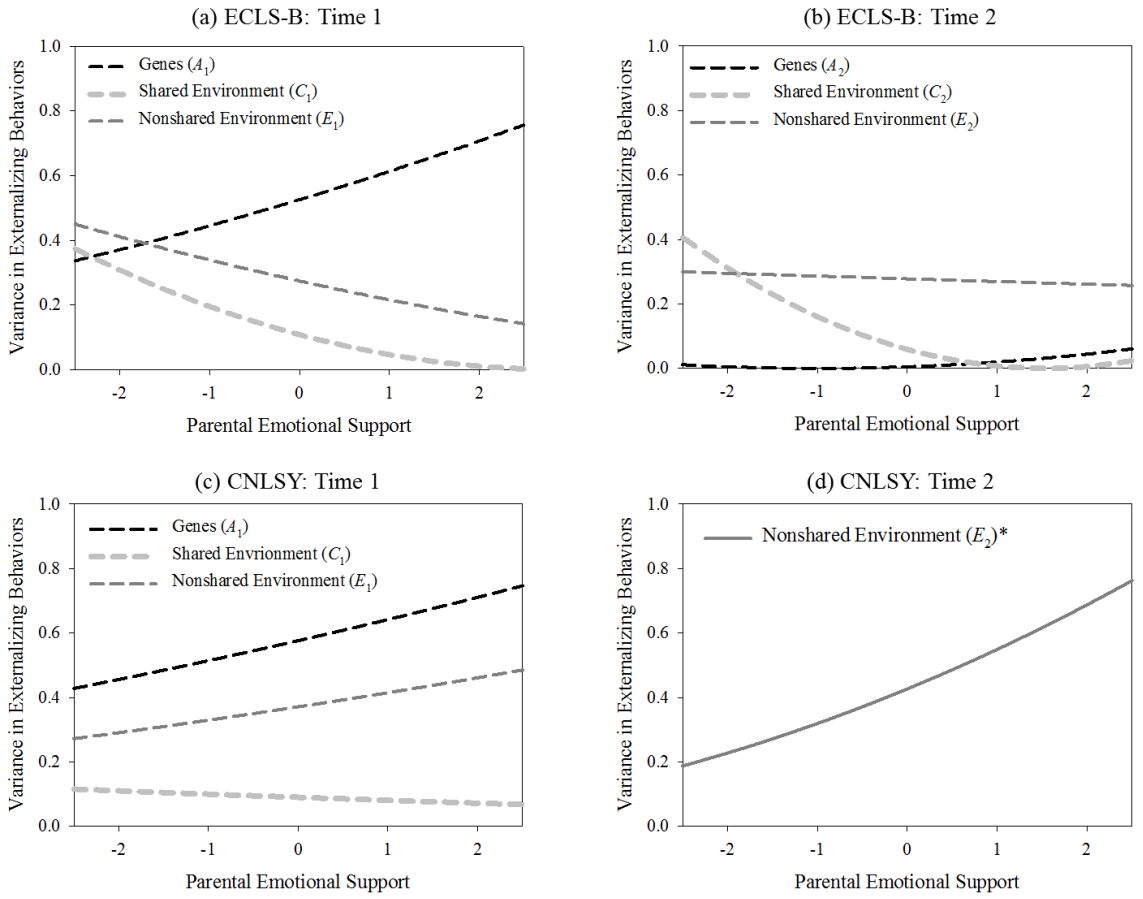

Figure 4: Graphic representation of interactions with parental emotional support observed from model 3 (i.e., moderation effects of parental emotional support above and beyond those of socioeconomic status). Upper panels illustrate results from the ECLS-B subsample while lower panels illustrate results from the CNLSY subsample. Left panels illustrate genetic and environmental influences at time 1 while right panels illustrate genetic and environmental influences that were unique to time 2. Black lines represent genetic influences, light grey lines represent shared environmental influences, and dark grey lines represent non-shared environmental influences. Solid lines indicate statistically significant G × E interactions. * $p < .05$. ** $p < .01$. Dashed lines indicate statistically insignificant ones. For the CNLSY subsample, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

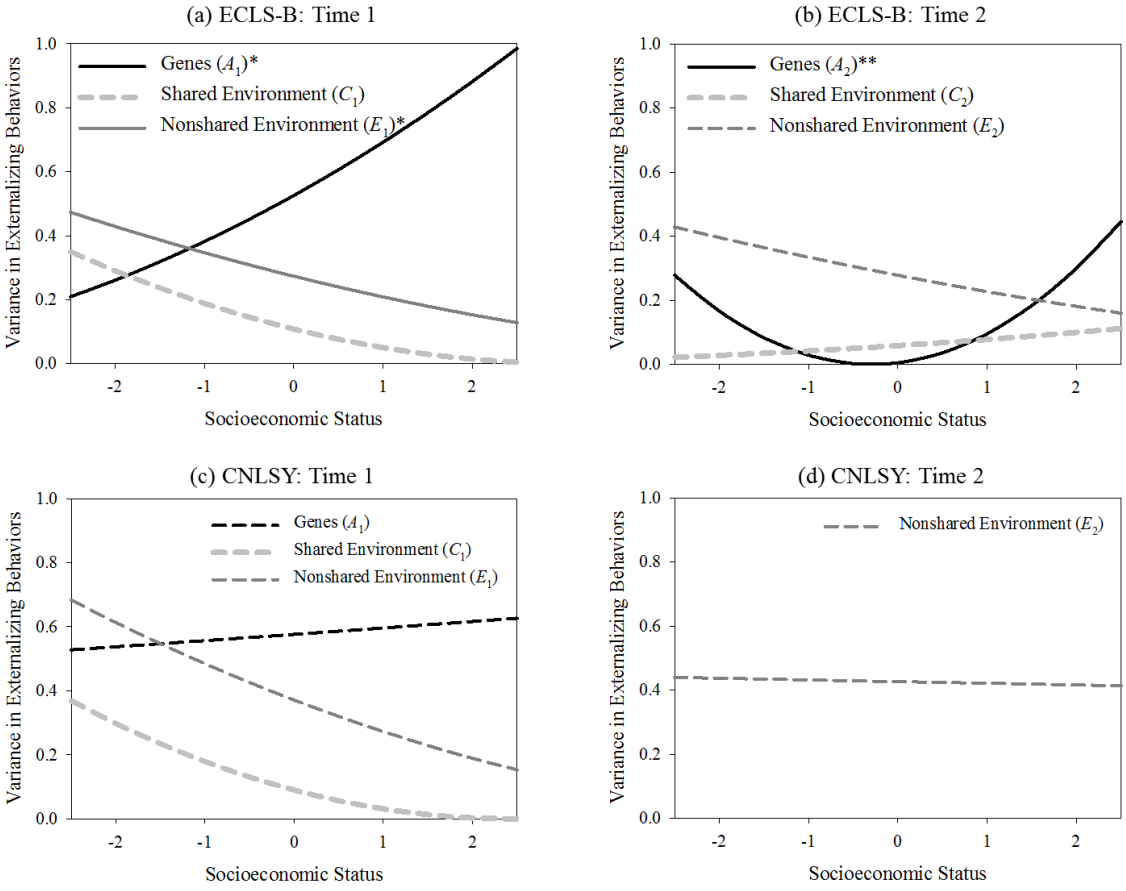

Figure 5: Graphic representation of interactions with socioeconomic status observed from model 3 (i.e., moderation effects of socioeconomic status above and beyond those of parental emotional support). Upper panels illustrate results from the ECLS-B subsample while lower panels illustrate results from the CNLSY subsample. Left panels illustrate genetic and environmental influences at time 1 while right panels illustrate genetic and environmental influences that were unique to time 2. Black lines represent genetic influences, light grey lines represent shared environmental influences, and dark grey lines represent non-shared environmental influences. Solid lines indicate statistically significant G × E interactions. * $p < .05$. ** $p < .01$. Dashed lines indicate statistically insignificant ones. For the CNLSY subsample, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

ECLS-B

Our model fit the ECLS-B data well (model fit statistics from main effect model: $\chi^2(42) = 40.109$, $p = .554$, RMSEA < .001, CFI = 1.000, TLI = 1.002). Once we have accounted for the effect of SES, parental emotional support no longer interacts with any latent genetic or environmental factors in externalizing behaviors. Externalizing behaviors was more influenced by A_1 ($a^2 = 53\%$, $c^2 = 11\%$, $e^2 = 27\%$) at time 1 but more by E_2 ($a^2 = 0\%$, $c^2 = 6\%$, $e^2 = 28\%$) at time 2 (see upper panels of Figure 4). Genetic and environmental influences at both times remained constant at all levels of parental emotional support.

In contrast to the null results on moderation effects of parental emotional support, most moderation effects of SES observed in model 2 remained statistically significant after accounting for the effects of parental emotional support. At time 1, externalizing behaviors were influenced more by E_1 ($a^2 = 26\%$, $e^2 = 43\%$) among children from families whose SES was 2*SD* below the sample average but more by A_1 ($a^2 = 88\%$, $e^2 = 15\%$) among children from families whose SES was 2*SD* above the sample average (see upper left panel of Figure 5). However, $C_1 \times$ SES interaction was no longer statistically significant ($p = .16$) after accounting for the effects of parental emotional support. C_1 accounted for 11% of the variance of time 1 externalizing behaviors at all levels of SES.

The $A_2 \times$ SES interaction observed in model 2 was also observed after we accounted for the effects of parental emotional support; A_2 accounted for 17% of the variance of time 2 externalizing behaviors among children from families whose SES was 2*SD* below the sample average but for 30% among children from families whose SES

was 2*SD* above the sample average (see upper right panel of Figure 5). After accounting for the effects of parental emotional support, influences of environmental factors unique to time 2 on externalizing behaviors remained constant (c^2 = 6%, e^2 = 28%) at all levels of SES. When examining moderation effects of parental emotional support and SES simultaneously, similar to results from models 1 and 2, relation of externalizing behaviors across the two time points was mediated mostly by genes. Of the total variance of time 2 externalizing behaviors, 61% was explained by A_1, 1% was explained by C_1, and 1% was explained by E_1; and these carried-over influences remained constant regardless of the amount of parental emotional support a child received or the level of SES.

CNLSY

None of the interactions observed for the ECLS-B subsample were replicated using the CNLSY subsample (model fit statistics from main effect model: $\chi^2(103)$ = 1445.616, p <. 001, RMSEA = .111, CFI = .471, TLI = .584). Moderation effects of parental emotional support and SES observed when examining the two moderators simultaneously were similar to those observed in models 1 and 2. Externalizing behaviors at time 1 were influenced mostly by A_1 and E_1 (a^2 = 58%, c^2 = 9%, e^2 = 37%) and these genetic and environmental influences at time 1 remained constant at all levels of parental emotional support and all levels of SES. The only statistically significant interaction was observed at time 2 with parental emotional support. When accounting for the effects of SES, E_2 accounted for 23% of the variance of time 2 externalizing behaviors among children who received parental emotional support that was 2*SD* below sample average

but for 69% among those who received parental emotional support that was 2*SD* above sample average (see lower right panel of Figure 4). In contrast, no moderation effects of SES were observed at time 2 (see lower right panel of Figure 5). After accounting for the effects of parental emotional support, influences of E_2 on externalizing behaviors remained constant (e^2 = 43%) at all levels of SES. Consistent with findings from models 1 and 2 and those from the ECLS-B subsample, relation of externalizing behaviors across the two time points was mediated mostly by genes. Of the total variance of time 2 externalizing behaviors, 49% was explained by A_1, 6% was explained by C_1, and 0% was explained by E_1; and these carried-over influences remained constant regardless of the amount of parental emotional support a child received or the level of SES.

Discussion[5]

To better understand the complex etiology of externalizing behaviors, researchers have increasingly turned their attention towards G × E interactions. Given the important role of parents in socializing young children and the importance of SES in various aspects of child development, indices of both parenting and social class have been viewed as promising candidate moderators of genetic influences on externalizing behaviors. While there have been a number of reports on G × parenting and G × SES interactions in the literature, the directions of these interactions have been inconsistent. It is possible that inconsistencies across studies derive from substantively meaningful differences in individuals and variables measured in the different studies. However, it is also possible that inconsistencies derive from haphazard, less systematic, reasons. Close replications are essential to distinguish between these possibilities. The current study tested for G × E involving both parental emotional support and SES. We made use of data from two population-based samples: the ECLS-B and the CNLSY. Findings were inconsistent across the two samples. When examining the moderation effects of parental emotional support and SES one at a time, results from the ECLS-B indicated that genes explained more variance of externalizing behaviors at lower levels of parental emotional support and at higher levels of SES. In contrast, results from the CNLSY subsample indicated no evidence for G × E. When examining moderation effects of parental emotional support

[5] Portions of this chapter have been previously published as Cheung, A. K., Harden, K. P., & Tucker-Drob, E. M. (2014). Gene × Environment interactions in early externalizing behaviors: Parental emotional support and socioeconomic context as moderators of genetic influences? *Behavior Genetics*, *44*(5), 468-486.

and SES simultaneously, findings were similar to those when we examined their effects one at a time.

One reason for the differences in results across our two samples could be the difference in birth cohorts involved. Twins in ECLS-B were all born in 2001 while siblings in CNLSY were from different birth cohorts. Siblings in CNLSY reached the same age in different years and data were collected on these siblings over a course of 20 years from 1986 to 2006. Data collected in different years may not be comparable and hence may affect the validity of results obtained in CNLSY. For example, total family income reported when a child was 4 or 5 years old might not be comparable across survey years due not only to inflation, but also to differences in the experience of social class across historical time. We attempted to eliminate issues associated with inflation by adjusting the reported amount of total family income to 2008 dollars. However, we were not able to correct for more qualitative differences in social class, for instance, that result from changes in social and educational policy over time. It is therefore possible that inclusion of multiple birth cohorts from the CNLSY obscured G × E interactions that would have been otherwise observed.

A second difference between the ECLS-B and CLNLSY studies that may have contributed to the inconsistency of findings concerns measurement of parental emotional support. Parental emotional support was measured using videotaped observational data from a semi-structured task in ECLS-B, whereas it was measured using interviewers' general observation and parents' self-report during home visits in CNLSY. Ratings of behavior during a semi-structured task may not be completely comparable to those

observed passively during a home visit. In ECLS-B, observational data from a semi-structured task provide a limited scope of parent-child interaction in natural settings. In CNLSY, interviewers' presence and interaction with parents might have biased their ratings of the parents' behaviors during the home visits and parents' self-report on their level of emotional support might have been biased by factors such as social desirability.

If we were to interpret our ECLS-B results, it appears that environmental moderators that are positively correlated in the population and that are both commonly interpreted as "good" environments may moderate genetic influences differently. Specifically, G × parental emotional support interaction observed for the ECLS-B subsample is consistent with the pattern predicted by the diathesis-stress hypothesis. That is, genes had a less influence on a child's level of externalizing behaviors at higher levels of parental emotional support. This is consistent with the view that parental emotional support facilitates at-risk children's development of self-control (Belsky & Beaver, 2011; Bradley & Corwyn, 2008; Eisenberg et al., 2005; Patterson et al., 1990) and hence their inhibition of externalizing behaviors. Despite the strong positive correlation between parental emotional support and SES, the direction of the G × SES interaction observed was the opposite of that of G × parental emotional support interaction. The pattern of G × SES interaction observed for the ECLS-B subsample is consistent with the pattern predicted by the social push hypothesis. That is, genes had a greater influence on a child's level of externalizing behaviors at higher levels of SES. This is consistent with the view that externalizing behaviors are explained more by genes among children raised by parents with more resources and fewer life constraints because environmental risk is

minimal in nurturing environments. Though parents with more socioeconomic resources tend to show more positive parenting such as emotional support (Conger et al., 1992; Dodge, Pettit, & Bate, 1994) and these two factors are both negatively correlated with externalizing behaviors (Barry et al., 2005; Keiley et al., 2000; McLoyd & Smith, 2002; Murray et al., 2010; Stormshak et al., 2000), results from the ECLS-B subsample indicate that parental emotional support and SES moderate genetic contributions to externalizing behaviors in different ways. Different patterns of moderation effects by correlated moderators could therefore be a promising factor to consider in future investigation of G × E interactions.

Our study demonstrated that research on G × E interactions in externalizing behaviors is indeed complicated. We modeled interactions using sophisticated quantitative methods; we controlled for the effects of gene-environment correlations, child genetic and non-genetic influences on parental emotional support, and we employed a longitudinal approach that controlled for previous levels of externalizing behaviors. Yet, despite these strengths we found inconsistent results across studies. Thus, patterns of G × E interaction on externalizing development vary remarkably across studies, even when strong methods are applied and the studies producing the data only differ superficially.

Conclusion[6]

Our study demonstrated that G × E interaction research on externalizing behaviors is still in its early stage and existing findings, including ours, should be considered tenuous until a more consistent set of results can be obtained across samples. This is a good example of the inconsistency in the current G × E interaction literature on externalizing behaviors. We are among the first to examine covarying social moderators simultaneously and to use two population-based samples in studying G × E interaction effects on externalizing behaviors. Our results raise the possibility that strongly correlated contextual factors may modulate genetic influences on externalizing behaviors differently, and that G × E interactions may differ across studies that only differ superficially. Future quantitative behavior genetics research on externalizing behaviors should examine the impact of covarying social moderators on the patterns of G × E interactions observed and conduct replication studies to better understand how findings may vary by subtleties in the environment and construct indices. Even non-replications can be informative to researchers in refining our understanding of G × E interaction effects on externalizing behaviors.

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Appendix[7]

In this Appendix, we report results of models that follow van der Sluis and colleagues (2012)'s suggestion to allow for moderated covariances between the moderators (SES and parental emotional support) and the phenotypes (externalizing behaviors at both waves). Note that these additions only apply to models in which moderators are measured separately for each twin. Because SES was measured at the family level for ECLS-B families, model with SES as the only moderator (i.e., model 2) that was fitted to ECLS-B data was not altered.

For model 1, in which parental emotional support at time 1 is the only moderator, we fit a full bivariate model to allow moderated covariances between parental emotional support at time 1 and externalizing behaviors at both waves. We accomplished this by specifying the regression paths from the *A*, *C*, and *E* of parental emotional support at time 1 to externalizing behaviors at both waves to each contains a main effect term and an interaction with parental emotional support at time 1. Table 10 lists the parameter estimates from model 1 after controlling for the moderated covariances between parental emotional support at time 1 and externalizing behaviors at both waves.

[7] Portions of this chapter have been previously published as Cheung, A. K., Harden, K. P., & Tucker-Drob, E. M. (2014). Gene × Environment interactions in early externalizing behaviors: Parental emotional support and socioeconomic context as moderators of genetic influences? *Behavior Genetics*, *44*(5), 468-486.

Path	ECLS-B		CNLSY	
	Main Effect	Interaction	Main Effect	Interaction
b_{a1}	**.66(±.20)**	.08(±.13)	**.63(±.30)**	.03(±.19)
b_{c1}	**.43(±.19)**	-.04(±.21)	**.42(±.20)**	-.04(±.15)
b_{e1}	**.54(±.06)**	**-.09(±.07)**	.48(±1.40)	-.05(±.38)
b_{ab}	**.80(±.23)**	-.03(±.15)	**.60(±.27)**	-.05(±.14)
b_{cb}	-.02(±.35)	<-.01(±.17)	**.39(±.19)**	.05(±.12)
b_{eb}	**.13(±.09)**	.03(±.12)	-.01(±1.07)	.10(±.22)
b_{a2}	.30(±.48)	**-.19(±.18)**	-	-
b_{c2}	.19(±.49)	-.08(±.26)	-	-
b_{e2}	**.53(±.06)**	-.01(±.06)	**.69(±.20)**	.12(±.17)
b_{ma1}	-.18(±.43)	**.17(±.16)**	.16(±.25)	.01(±.13)
b_{mc1}	.02(±.19)	-.11(±.11)	**.18(±.15)**	**.11(±.10)**
b_{me1}	.00(±.09)	.04(±.08)	-.53(±1.23)	-.15(±.16)
b_{ma2}	-.22(±.42)	.04(±.19)	.08(±.20)	-.03(±.10)
b_{mc2}	.03(±.20)	-.03(±.10)	**.19(±.13)**	.07(±.08)
b_{me2}	.05(±.10)	-.01(±.09)	-.14(±.64)	.02(±.25)

Table 10: Main Effect and Interaction Parameter Estimates in Model 1 (Parental Emotional Support at Time 1 as Moderator) when accounting for the moderated covariances between parental emotional support and externalizing behaviors at both waves. Bolded = $p < .05$. In the model fitted to CNLSY data, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

For ECLS-B, at time 1, non-shared, but not shared, environment influenced externalizing behaviors differentially by levels of parental emotional support at time 1. C_1 accounted for 18% of the variance of time 1 externalizing behaviors regardless of the level of parental emotional support a child received. E_1 accounted for 52% of the variance of time 1 externalizing behaviors among children who received parental emotional support that was 2*SD* below sample average but for 12% among those who received parental emotional support that was 2*SD* above sample average. For CNLSY, parental emotional support at time 1 no longer moderated the effect of E_2. That is, non-shared environmental influence unique to time 2 remained constant (e^2 = 47%) regardless of the amount of parental emotional support a child received.

For model 2, in which SES at time 1 is the only moderator, we fit an expanded univariate model instead of a full bivariate model to our CNLSY data. It was not appropriate to decompose the variance of SES into *A*, *C*, and *E* components in this model because SES differed across siblings mainly due to their differences in age, which reflects differences in family income over time. To achieve the same level of statistical control as would be provided by the full bivariate model, in which the moderator is itself decomposed into *A*, *C*, and *E* components, we modeled both linear and quadratic regressions of externalizing behaviors at both waves on both siblings' SES at time 1 and allowed these regressions coefficients to differ across sibling types. Tables 11 and 12 list the parameter estimates from model 2 after controlling for the moderated covariances between SES at time 1 and externalizing behaviors at both waves. When compared to the results presented in our main result section, no major changes were observed.

Path	ECLS-B		CNLSY	
	Main Effect	Interaction	Main Effect	Interaction
b_{a1}	**.61(±.16)**	**.17 (±.10)**	**.79(±.31)**	-.04(±.11)
b_{c1}	**.45(±.18)**	**-.17 (±.12)**	.26(±.43)	-.02(±.16)
b_{e1}	**.62(±.06)**	**-.08 (±.04)**	**.62(±.22)**	-.08(±.09)
b_{ab}	**.83(±.15)**	-.07 (±.12)	**.73(±.27)**	-.05(±.08)
b_{cb}	.07(±.28)	-.02 (±.18)	.23(±.37)	-.01(±.10)
b_{eb}	**.19(±.09)**	-.06 (±.08)	-.06(±.40)	.01(±.10)
b_{a2}	.15(±.33)	**.26 (±.18)**	.00(±.24)	.00(±.12)
b_{c2}	.24(±.37)	-.04 (±.24)	.00(±.15)	.00(±.11)
b_{e2}	**.58(±.06)**	-.05 (±.06)	**.66(±.21)**	-.05(±.08)

Table 11: Main Effect and Interaction Parameter Estimates in Model 2 (SES at Time 1 as Moderator) when accounting for the moderated covariances between SES and externalizing behaviors at both waves. Bolded = $p < .05$. The model and results for ECLS-B are the same as those described and reported in the main text.

Sibling Pair	Path	Estimate	
		Linear	Quadratic
Full-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	**-.14(±.09)**	-.01(±.02)
	$EXT_{1,1}$ ON $SES_{1,2}$	**-.19(±.09)**	**-.04(±.02)**
	$EXT_{1,2}$ ON $SES_{1,1}$	**-.19(±.09)**	**-.04(±.02)**
	$EXT_{1,2}$ ON $SES_{1,2}$	**-.14(±.05)**	-.01(±.02)
	$EXT_{2,1}$ ON $SES_{1,1}$	**-.17(±.08)**	**-.02(±.02)**
	$EXT_{2,1}$ ON $SES_{1,2}$	**-.11(±.08)**	**-.02(±.02)**
	$EXT_{2,2}$ ON $SES_{1,1}$	**-.11(±.08)**	**-.02(±.02)**
	$EXT_{2,2}$ ON $SES_{1,2}$	**-.17(±.08)**	**-.02(±.02)**
Half-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	-.12(±.19)	-.01(±.05)
	$EXT_{1,1}$ ON $SES_{1,2}$	-.13(±.18)	-.02(±.03)
	$EXT_{1,2}$ ON $SES_{1,1}$	-.13(±.09)	-.02(±.03)
	$EXT_{1,2}$ ON $SES_{1,2}$	-.12(±.19)	-.01(±.05)
	$EXT_{2,1}$ ON $SES_{1,1}$	-.14(±.16)	-.02(±.03)
	$EXT_{2,1}$ ON $SES_{1,2}$	-.07(±.16)	-.01(±.03)
	$EXT_{2,2}$ ON $SES_{1,1}$	-.07(±.16)	-.01(±.03)
	$EXT_{2,2}$ ON $SES_{1,2}$	-.14(±.16)	-.02(±.03)
Unidentified-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	<-.01(±.29)	<.01(±.05)
	$EXT_{1,1}$ ON $SES_{1,2}$	-.09(±.03)	-.01(±.06)
	$EXT_{1,2}$ ON $SES_{1,1}$	-.09(±.03)	-.01(±.06)
	$EXT_{1,2}$ ON $SES_{1,2}$	<-.01(±.29)	<.01(±.05)
	$EXT_{2,1}$ ON $SES_{1,1}$	-.09(±.26)	.01(±.05)
	$EXT_{2,1}$ ON $SES_{1,2}$	-.10(±.26)	-.02(±.05)
	$EXT_{2,2}$ ON $SES_{1,1}$	-.10(±.26)	-.02(±.05)
	$EXT_{2,2}$ ON $SES_{1,2}$	-.09(±.26)	.01(±.05)

Table 12: Estimated Coefficients of Regressing Externalizing Behaviors at Both Waves on SES in Model 2 (SES at Time 1 as Moderator) when accounting for the moderated covariances between SES and externalizing behaviors at both waves – CNLSY. Bolded = $p < .05$. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair.

For model 3, in which both parental emotional support and SES at time 1 were both included as the moderators, we simultaneously implemented the above described elaborations. Tables 13 and 14 list the parameter estimates from model 3 after controlling for the moderated covariances between each moderator and externalizing behaviors at both waves. When compared to the results presented in our main result section, no major changes were observed in our ECLS-B results. However, for CNLSY results, parental emotional support at time 1 no longer moderated the effect of E_2. That is, non-shared environmental influence unique to time 2 remained constant (e^2 = 43%) regardless of the amount of parental emotional support a child received.

Path	ECLS-B			CNLSY		
		Interaction			Interaction	
	Main Effect	Parental Emotional Support	SES	Main Effect	Parental Emotional Support	SES
b_{a1}	**.71(±.17)**	.05(±.12)	**.11(±.10)**	**.75(±.28)**	.04(±.13)	.02(±.14)
b_{c1}	**.35(±.26)**	-.06(±.23)	-.09(±.16)	.29(±.33)	-.01(±.17)	-.10(±.17)
b_{e1}	**.52(±.06)**	-.06(±.07)	**-.06(±.05)**	**.61(±.21)**	.04(±.11)	-.08(±.11)
b_{ab}	**.82(±.14)**	-.06(±.12)	-.03(±.13)	**.69(±.23)**	-.02(±.14)	-.06(±.11)
b_{cb}	-.10(±.42)	.05(±.20)	-.04(±.20)	.24(±.29)	.09(±.15)	.05(±.13)
b_{eb}	**.09(±.09)**	.06(±.13)	-.04(±.09)	-.03(±.35)	.07(±.14)	.04(±.13)
b_{a2}	-.08(±.38)	-.07(±.17)	**-.25(±.15)**	-	-	-
b_{c2}	.20(±.52)	-.13(±.28)	.02(±.28)	-	-	-
b_{e2}	**.52(±.06)**	.03(±.07)	-.06(±.06)	.65(±.17)	.08(±.09)	-.01(±.11)
b_{ma1}	-.09(±.36)	.15(±.18)	-	.14(±.43)	.01(±.17)	-
b_{mc1}	.06(±.20)	**-.14(±.13)**	-	.10(±.22)	.02(±.12)	-
b_{me1}	-.01(±.09)	.04(±.08)	-	-.11(±.37)	-.04(±.17)	-
b_{ma2}	-.16(±.44)	.10(±.19)	-	.10(±.38)	-.09(±.15)	-
b_{mc2}	.09(±.25)	-.09(±.13)	-	.12(±.20)	.05(±.11)	-
b_{me2}	.04(±.10)	-.02(±.09)	-	-.05(±.33)	.03(±.15)	-

Table 13: Main Effect and Interaction Parameter Estimates in Model 3 (Two Moderators) when accounting for the moderated covariances between the moderators (SES and parental emotional support) and the phenotypes (externalizing behaviors at both waves). Bolded = $p < .05$. In the model fitted to CNLSY data, results from the main effect model suggested that A_2 and C_2 had no effect on externalizing behaviors and E_2 is therefore the sole latent factor of externalizing behaviors at time 2, above and beyond the main effects of moderators and influences carried-over from time 1.

Sibling Pair	Path	Estimate	
		Linear	Quadratic
Full-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	**-.11(±.10)**	-.01(±.03)
	$EXT_{1,1}$ ON $SES_{1,2}$	**-.18(±.10)**	**-.04(±.01)**
	$EXT_{1,2}$ ON $SES_{1,1}$	**-.18(±.10)**	**-.04(±.02)**
	$EXT_{1,2}$ ON $SES_{1,2}$	**-.11(±.10)**	-.01(±.03)
	$EXT_{2,1}$ ON $SES_{1,1}$	**-.15(±.09)**	**-.02(±.02)**
	$EXT_{2,1}$ ON $SES_{1,2}$	-.06(±.09)	-.01(±.02)
	$EXT_{2,2}$ ON $SES_{1,1}$	-.06(±.09)	-.01(±.02)
	$EXT_{2,2}$ ON $SES_{1,2}$	**-.15(±.09)**	**-.02(±.02)**
Half-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	-.10(±.20)	-.01(±.06)
	$EXT_{1,1}$ ON $SES_{1,2}$	-.08(±.20)	-.02(±.03)
	$EXT_{1,2}$ ON $SES_{1,1}$	-.08(±.20)	-.02(±.03)
	$EXT_{1,2}$ ON $SES_{1,2}$	-.10(±.20)	-.01(±.06)
	$EXT_{2,1}$ ON $SES_{1,1}$	-.10(±.17)	-.02(±.04)
	$EXT_{2,1}$ ON $SES_{1,2}$	<-.01(±.17)	.01(±.03)
	$EXT_{2,2}$ ON $SES_{1,1}$	<-.01(±.17)	.01(±.03)
	$EXT_{2,2}$ ON $SES_{1,2}$	-.10(±.17)	-.02(±.04)
Unidentified-Sibling	$EXT_{1,1}$ ON $SES_{1,1}$	.06(±.37)	.06(±.25)
	$EXT_{1,1}$ ON $SES_{1,2}$	.06(±.44)	.09(±.23)
	$EXT_{1,2}$ ON $SES_{1,1}$	.06(±.44)	.09(±.23)
	$EXT_{1,2}$ ON $SES_{1,2}$	.06(±.37)	.06(±.25)
	$EXT_{2,1}$ ON $SES_{1,1}$	.06(±.34)	.12(±.22)
	$EXT_{2,1}$ ON $SES_{1,2}$	-.05(±.36)	-.07(±.21)
	$EXT_{2,2}$ ON $SES_{1,1}$	-.05(±.36)	-.07(±.21)
	$EXT_{2,2}$ ON $SES_{1,2}$	.06(±.34)	.12(±.22)

Table 14: Estimated Coefficients of Regressing Externalizing Behaviors at Both Waves on SES in Model 3 (Two Moderators) when accounting for the moderated covariances between the moderators (SES and parental emotional support) and the phenotypes (externalizing behaviors at both waves) – CNLSY. Bolded = $p < .05$. SES = socioeconomic status. EXT = externalizing behaviors. The first number in the subscripts represents the time point when measurements were made and the second one represents the sibling in a pair.

Although some changes were observed when comparing results obtained before and after controlling for moderated covariances between moderators and phenotypes, these changes did not drastically change our overall results and our interpretation of them. It is important to point out once again that our paper focuses on the importance of replications in research on G × E interactions. In sum, our study demonstrated that the commonly observed inconsistency in the current G × E interaction literature on early externalizing behaviors persists even when very close approaches to replication are implemented.

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Vita

Amanda Kingsze Cheung started graduate school at The University of Texas at Austin in September, 2011. She received her B.S. in Psychology from the University of Wisconsin-Madison in 2009 and had worked as a certified examiner and research project assistant at the Pitt Parents and Children Lab at the University of Pittsburgh. In particular, she is interested in studying individual differences in the development of externalizing behaviors.

Email: akcheung@utexas.edu

This thesis was typed by Amanda Kingsze Cheung.